ERCB Energy Resources Conservation Board
Calgary Office 640 – 5 Avenue SW, Calgary, Alberta, Canada T2P 3G4 Tel 403-297-8311 Fax 403-297-7336 www.ercb.ca

Directive 020

Revised edition June 9, 2010
Effective July 1, 2010

Well Abandonment

The Energy Resources Conservation Board (ERCB/Board) has approved this directive on June 9, 2010.

B. T. McManus, Q.C.
Vice Chairman

Contents

1 Introduction 3
1.1 Purpose of the Directive 3
1.2 Requirements and Recommendations 3
1.3 What's New in This Edition 3
1.4 Overview 5
2 Requirements for Nonroutine Abandonment Requests and for Notification and Reporting 6
2.1 Obtaining Approval for Nonroutine Abandonment Operations 6
2.2 ERCB Notification 6
2.3 ERCB Reporting Requirements 6
3 Previously Abandoned Wells/Zones 7
3.1 Previously Abandoned Wells (Cut and Capped) 7
3.2 Previous Zonal Abandonments 7
3.3 Leaking Wells/Lowering Casing Stubs 7
3.4 Reentry Wells 7
4 Open-Hole Abandonment Requirements 8
4.1 Open-Hole Abandonment of Non-Oil Sands Wells 8
4.2 Open-Hole Abandonment of Wells That Have Penetrated Oil Sands Zones 12
4.3 Wells in the Cold Lake/Athabasca Oil Sands Area 13
4.4 Wells in the Peace River Oil Sands Area 14
4.5 Confirming Plug Placement 16
4.6 Oil Sands Evaluation Wells and Test Hole Wells 17
5 Cased-Hole Abandonment Requirements 18
5.1 Cement Evaluation 18
5.1.1 Cement Top Determination 19
5.1.2 Identification of Porous Intervals 19
5.1.3 Remedial Cementing 19
5.2 Use of Inhibitor 19
5.3 Wells Not Penetrating Oil Sands Zones 19
5.3.1 Noncompleted Wells 19
5.3.2 Wells With a Cemented Liner 19
5.3.3 Wells With an Uncemented Liner 20

5.3.4 Wells With Casing Patching, Casing Failures, and Previously Cement Squeezed Intervals20
5.3.5 Zonal Abandonment Within a Completed Well 21
5.3.6 Completed Horizontal Wells in a Single Formation 23
5.3.7 Completed Horizontal Wells Across Multiple Formations 25
5.4 Wells Penetrating Oil Sands Zones 25
5.4.1 Thermal Cement 26
5.4.2 Noncompleted Wells 26
5.4.3 Wells With a Cemented Liner 26
5.4.4 Wells With an Uncemented Liner 26
5.4.5 Wells with Casing Patching, Casing Failures, and Previously Cement Squeezed Intervals 27
5.4.6 Completed Wells 27
5.4.7 Completed Horizontal Wells in a Single Formation 30
5.4.8 Completed Horizontal Wells Across Multiple Formations 32
5.5 Groundwater Protection 32
5.5.1 Remedial Cementing of Protected intervals 32
5.5.2 Requesting a Groundwater Protection Waiver 34
6 Confirming Location of Cement Plugs 34
6.1 Methods for Confirming Plug Locations 34
6.2 Plug Log Submission Requirements 36
7 Testing and Inspection Requirements 37
7.1 Gas Migration (GM) Testing for Open- and Cased-Hole Wells 37
7.1.1 Gas Migration Test Area 37
7.1.2 Notification of Gas Migration 37
7.2 Fluid Level Test for Open-Hole Wells 38
7.3 Surface Casing Vent Flow Test for Cased-Hole Wells 39
7.3.2 Determination of Stabilized Shut-in Surface Casing Pressure 39
7.3.3 Determination of Serious or Non-Serious Vent Flow 39
7.3.4 Notification of SCVF 40
8 Surface Abandonment 41
8.1 Cutting and Capping 41
9 Compliance Assurance 43
9.1 Compliance Assurance and Enforcement Process 43

Appendices

1 Definitions for the Purposes of *Directive 020* 44
2 Suggested Procedure for Gas Migration Testing 45
3 Suggested Procedure for Surface Casing Vent Flow Testing 46

Figures

1 Oil sands area boundary 9
2a Plug placement examples for Southern Plains/Foothills 10
2b Plug placement examples for Central Plains 11
2c Plug placement examples for Northwest Plains 11
2d Plug placement example for Northeast Plains 12
3 Plug placement example for Cold Lake/Athabasca Oil Sands Area 14
4 Plug placement example for Peace River Oil Sands Area 16
5 Unacceptable plugs 17
6 Gas migration test area 38
7 Site inspection region 40
8 Examples of cased-hole abandonment for non-level-A intervals 42
9 Examples of cased-hole abandonment for level-A intervals 42

1 Introduction

1.1 Purpose of the Directive

The Energy Resources Conservation Board (ERCB) *Directive 020: Well Abandonment* details the minimum requirements for abandonments, casing removal, zonal abandonments, and plug backs as required under Sections 3.013 of the *Oil and Gas Conservation Regulations*.

The objective of a well abandonment is to cover all nonsaline groundwater (water with total dissolved solids [TDS] less than 4000 milligrams per litre [mg/l]) and to isolate or cover all porous zones.

All open-hole and cased-hole abandonments must be conducted in accordance with the requirements in this directive.

This edition of *Directive 020* is effective July 1, 2010.

1.2 Requirements and Recommendations

ERCB requirements are identified throughout *Directive 020* and are numbered sequentially within each section. The term "must" indicates a requirement, while "recommends" indicates recommended practices.

1.3 What's New in This Edition

Changes in this edition of *Directive 020* are highlighted below:

- Overview (Section 1.4): The abandonment of any well associated with a salt cavern or an in situ coal gasification/liquification scheme is nonroutine.
- ERCB Notification (Section 2.2): Notification to the ERCB through the Digital Data Submission (DDS) system of abandonment is required prior to both zonal and wellbore abandonments. This requirement has been modified and incorporated into *Directive 020* from *Directive 072*.
- Previously Abandoned Zones/Wells (Section 3): Nonabandoned wells with existing zonal abandonments that were compliant at the time the zonal abandonment took place are not required to be reabandoned to current standards. Two exceptions to this are detailed.
- Open-Hole Abandonment Requirements (Section 4): The four separate program areas for open-hole abandonments have been removed and replaced with abandonments based on porosity and geological formations. For the open-hole abandonment, now a cement plug must extend from 15 metres (m) below the top of the Mannville Group (or equivalent) to 15 m into the next casing string. All plugs run at a depth greater than 1500 m must be a minimum length of 60 m, and they must extend a minimum of 30 m below and a minimum of 30 m above the zone being covered. Following completion of the plugging program, the wellbore must be filled with nonsaline water.
- Confirming Plug Placement (Section 4.5): A low plug is now defined as a plug with a top that is less than 15 m (or 30 m for zones below 1500 m) above the top of the zone it was intended to cover.
- Oil Sands Evaluation Wells and Test Hole Wells (Section 4.6): Downhole abandonment operations on oil sands evaluation and test hole wells that are outside of the surface mineable areas must be completed prior to rig release. Any drop in cement due to pipe displacement must be replaced by an equivalent volume of nonsaline water. Test holes

outside of a designated oil sands area must be filled with cement that has a final compressive strength of at least 3500 kilopascals (kPa) after curing for 48 hours.

- Cased-Hole Abandonment Requirements (Section 5): This section now includes the definition and abandonment requirements for level-A intervals. Cement squeezed intervals that are drilled out must be pressure tested at a stabilized pressure equal to the greater of 7000 kPa or 85 per cent of the current or expected reservoir pressure of the perforations that will be open to the wellbore. A retainer that has not been activated can be substituted where a permanent bridge plug is required.
- Use of Inhibitor (Section 5.2): This section outlines the types of fluid that may be used inside the casing.
- Wells With a Cemented Liner (Section 5.3.2): The use of a permanent bridge plug (or a retainer that has not been activated) capped with cement is now an approved method of abandonment of the liner top.
- Noncompleted Wells With Liners: The abandonment method depends on the abandonment type (wells penetrating or not penetrating oil sands zones). The requirements for wells not penetrating oil sands zones are set out in Sections 5.3.2 and 5.3.3; the requirements for wells penetrating oil sands zones are set out in Sections 5.4.3 and 5.4.4.
- Wells With Casing Patching, Casing Failures, and Previously Cement Squeezed Intervals (Sections 5.3.4 and 5.4.5): These new sections set out the requirements for abandonment of wells with casing patches, casing failures, and previously cement squeezed intervals.
- Zonal Abandonment Within a Completed Well (Section 5.3.5): This section clarifies that the bridge plug used must be a permanent bridge plug. If more than one year has elapsed from the setting and pressure testing of a bridge plug prior to capping with cement, the bridge plug must be pressure tested again (Option 1). It is also acceptable to run a continuous cement plug across multiple completed zones (Option 5).
- Groundwater Protection (Section 5.5): This section now includes a definition of a "protected interval" that is above the base of groundwater protection (BGWP) and stipulates where segregation is required.
- Remedial Cementing of Protected Intervals (Section 5.5.1): This section has been modified and now includes the use of a retainer.
- Requesting a Groundwater Protection Waiver (Section 5.5.2): The option for showing the absence of deleterious crossflow between BGWP and lower saline aquifers is no longer available for the groundwater protection waiver. The requirements for the written assessment for a groundwater protection waiver have been modified
- Gas Migration Testing for Open- and Cased-Hole Wells (Section 7.1): Gas migration testing must be conducted on all wells that do not have a surface casing vent assembly. Gas migration testing is required for oil sands evaluation and test hole wells that are within the gas migration test area (Figure 6).
- Fluid Level Test for Open-Hole Wells (Section 7.2): Fluid level testing is required for oil sands evaluation and test hole wells where the fluid required to fill the hole does not coincide with the calculated pipe displacement volume.
- Procedure for SCVF Test (Section 7.3.1): If a vent flow is detected by a bubble test, a stabilized shut-in pressure must be obtained. The shut-in pressure is considered stabilized if the change in pressure is less than 2 kPa/hour over a 6-hour period.

- Surface Abandonment (Section 8): The casing strings must be capped at surface with a steel plate that is fastened and installed in a manner to prevent any potential for pressure to build up within the casings, while restricting access to the casing strings at surface.
- Cutting and Capping (Section 8.1): The "wedding cake" style cut and cap is now permitted if all casing strings are capped in a manner that will prevent pressure build-up within the casing. If the well is located in an area where surface mining will be conducted, a cement plug must be circulated from the uppermost abandonment plug to 15 m below the intended strip mining depth and the casing must be cut at intervals agreed upon by the mining operator.
- Definitions for the Purposes of *Directive 020* (Appendix 1): This appendix has been added.

1.4 Overview

When planning to abandon a well, a licensee has to determine whether the planned abandonment operation will be routine or nonroutine, as defined by this directive. A planned abandonment operation is **routine** if it meets all the requirements that apply to the well based on

- the type of well being abandoned,
- the well's geographic location,
- the impact of the well on any oil sands zones, and
- the absence of a wellbore problem.

Routine abandonments are any operations that comply with the requirements specified in this directive. **Routine** abandonment operations **do not** require ERCB approval before work is started. Nonroutine abandonments consist of any operations that vary from the requirements in this directive. **Nonroutine** abandonment operations **do** require ERCB approval before work is started.

Some examples of **nonroutine** abandonment operations are

- the abandonment of any well that is associated with a salt cavern;
- the abandonment of any well that is associated with an in situ coal gasification scheme;
- the planned abandonment of a well that has a wellbore problem, which includes
  - a fish-in-the-hole across two or more porous zones,
  - a leaking plug, or
  - a ghost hole across two or more porous zones;
- a reabandonment of a well;
- a planned surface abandonment of a well with flow remaining at surface;
- a planned surface abandonment of a well where cement does not cover all nonsaline groundwater zones;
- the planned use of cement plugs in a well in a manner that does not meet the requirements in this directive;
- the planned use of a bridge plug inside the surface casing;
- the planned use of any type of plugging device that will be set more than 15 metres (m) above the completion interval; and

- the planned removal of uncemented casing from the well in a manner that does not meet the requirements stated in this directive.

Note that the above is not a comprehensive list of the types of nonroutine abandonments.

This directive may not address every abandonment situation encountered in Alberta. If the licensee has questions about an abandonment operation, contact the ERCB Well Operations Section at 403-297-5290 *before* beginning any work. If an emergency situation occurs after hours or on a weekend, contact the appropriate ERCB Field Centre.

2 Requirements for Nonroutine Abandonment Requests and for Notification and Reporting

2.1 Obtaining Approval for Nonroutine Abandonment Operations

A nonroutine abandonment request must be submitted through the Digital Data Submission (DDS) system (Licence Abandonment : Non-routine Well Abandonment). In addition, an e-mail must be sent to ERCB Well Operations staff (ercb.WellOperations@ercb.ca) that includes the application, all supporting documentation, and the wellbore schematic.

The Well Operations Section will review the request and may ask the licensee to provide additional information regarding the nonroutine abandonment operation.

The licensee will be notified once the request has been approved or denied. The licensee must not begin operations prior to obtaining the approval and must conduct operations in accordance with the approval.

2.2 ERCB Notification

Notification is required prior to all open- and cased-hole well abandonment operations through the DDS system (Notifications: Field Surveillance). Notification for open- and cased-hole abandonments (including zonal abandonment) must be submitted prior to commencement of operations.

Oil sands evaluation wells and test-hole wells drilled within the surface mineable area are exempt from the notification requirements.

2.3 ERCB Reporting Requirements

Surface abandonments must be reported through the DDS system (Licence Abandonment: Well Licence Abandonment) within 30 days of completing the operation.

Note that a well licence abandonment submission cannot be made if there is a casing failure or a surface casing/vent flow report that is open and/or outstanding for the well licence. The surface casing vent flow/gas migration reports and casing failure reports must have a resolution entered, and the reports must be closed within the DDS system (ERCB: Incidents) prior to the submission of the well licence abandonment information.

Plug logs must be submitted to the ERCB's Resource Information Team, Well Log Group (e-mail: WellLogInquiries@ercb.ca) within 30 days of completing downhole operations. Refer to Appendix 1.

Industry is responsible to ensure that all work performed on a well is properly reported. (See *Directive 059: Well Drilling and Completion Data Filing Requirements*.)

3 Previously Abandoned Wells/Zones

3.1 Previously Abandoned Wells (Cut and Capped)

Wells that were abandoned to the standards in place prior to this edition of *Directive 020* are not required to be reabandoned to current standards. Exceptions to this are leaking wells and wells that are being reentered (see below).

3.2 Previous Zonal Abandonments

Active wells that have existing zonal abandonments and were compliant at the time of the zonal abandonment will not be required to be reabandoned to current standards. The exception to this is as follows.

For wells with existing zonal abandonments of level-A intervals (see Appendix 1 for definition of a Level-A interval), an additional cement plug must be circulated on top of the uppermost previously abandoned zone. This cement plug must be a minimum length of 30 vertical metres and have a minimum volume of 1 m^3. The base of this plug must be located below the BGWP.

If the uppermost previously abandoned zone's plug is above the BGWP,

- the plug must be drilled out, and
- an additional cement plug must be circulated on top of the uppermost previously abandoned zone. This cement plug must be a minimum length of 30 vertical metres. All perforations above this point must be abandoned to the current standard.

3.3 Leaking Wells/Lowering Casing Stubs

The current licensee of the well must submit a nonroutine abandonment request to the Well Operations Group for approval (see Section 2.1). The request must include the reason for the reentry. The licensee must also notify the mineral rights owner(s) and have an active surface lease agreement. Approval from Alberta Energy is required if the mineral rights have reverted back to the Crown. Operations to reenter the well for repair or lowering of the casing stub may proceed once the appropriate approvals are in place.

For wells and zones found to be leaking, the source of the leak must be identified and repaired in accordance with ERCB *Interim Directive (ID) 2003-01: 1)Isolation Packer Testing, Reporting, and Repair Requirements; 2) Surface Casing Vent Flow/Gas Migration Testing, Reporting, and Repair Requirements; 3)Casing Failure Reporting and Repair Requirements.* The leaking zone and all those above must be abandoned in accordance with *Directive 020*. The well must be abandoned at surface immediately after confirmation that the repair has been successful. The updated licence abandonment must be submitted through the DDS system as a reabandonment.

A licensee must follow the requirements of *Directive 056: Energy Development Applications and Schedules* when reentering an abandoned well for the purpose of production or if it is not the current licensee of the well.

3.4 Reentry Wells

Wells that are reentered must be abandoned in accordance with *Directive 020* from the reentry depth to surface. If there are abandoned zones below the reentry depth, the

requirements set out above for previous zonal abandonments (Section 3.2) and leaking wells/lowering casing stubs (Section 3.3) apply.

4 Open-Hole Abandonment Requirements

For the abandonment of an open-hole well, the licensee must set cement plugs of sufficient length and number to

- cover all nonsaline groundwater to the BGWP;
- cover all zones above the top of the Mannville Group (or equivalent; i.e., the Luscar or Blairmore Groups or Spirit River Formation); and
- isolate or cover all porous zones below the top of the Mannville Group (or equivalent).

To determine the BGWP depth for a well, refer to the BGWP query tool available on the ERCB Web site www.ercb.ca under the DDS system (ERCB : Reports : Base of Groundwater Protection).

Porous zones are defined as

- carbonates with effective porosity greater than 1 per cent,
- sandstones with effective porosity greater than 3 per cent,
- a zone with offset production regardless of the porosity, or
- any zone with drillstem test formation fluid recoveries greater than 300 linear metres or gas volumes greater than 300 cubic metres.

4.1 Open-Hole Abandonment of Non-Oil Sands Wells

For wells that are not in an oil sands area (Figure 1), the use of fillers and/or additives in the cement used for plugs is acceptable for open-hole abandonments if the compressive strength of the mixture is at least 3500 kPa after curing for 48 hours.

All zones above the top of the Mannville Group (or equivalent) must be covered with a plug that is placed in one or more stages.

- For wells where the top of the Mannville Group (or equivalent) is at a depth less than 1500 m true vertical depth (TVD), this plug must extend a minimum of 15 vertical metres below the top of the Mannville Group (or equivalent).
- For wells where the top of the Mannville Group (or equivalent) is at a depth greater than 1500 m TVD, this plug must extend a minimum of 30 vertical metres below the top of the Mannville Group (or equivalent).

Licensees must use the logs from the well to determine the exact plug placement for wells drilled deeper than the top of the Mannville Group (or equivalent).

All plugs run at a depth less than 1500 m TVD must be a minimum length of 30 vertical metres, and they must extend a minimum of 15 vertical metres below and a minimum of 15 vertical metres above the zone being covered.

All plugs run at a depth greater than 1500 m TVD must be a minimum length of 60 vertical metres, and they must extend a minimum of 30 vertical metres below and a minimum of 30 vertical metres above the zone being covered.

A plug may extend over more than one zone.

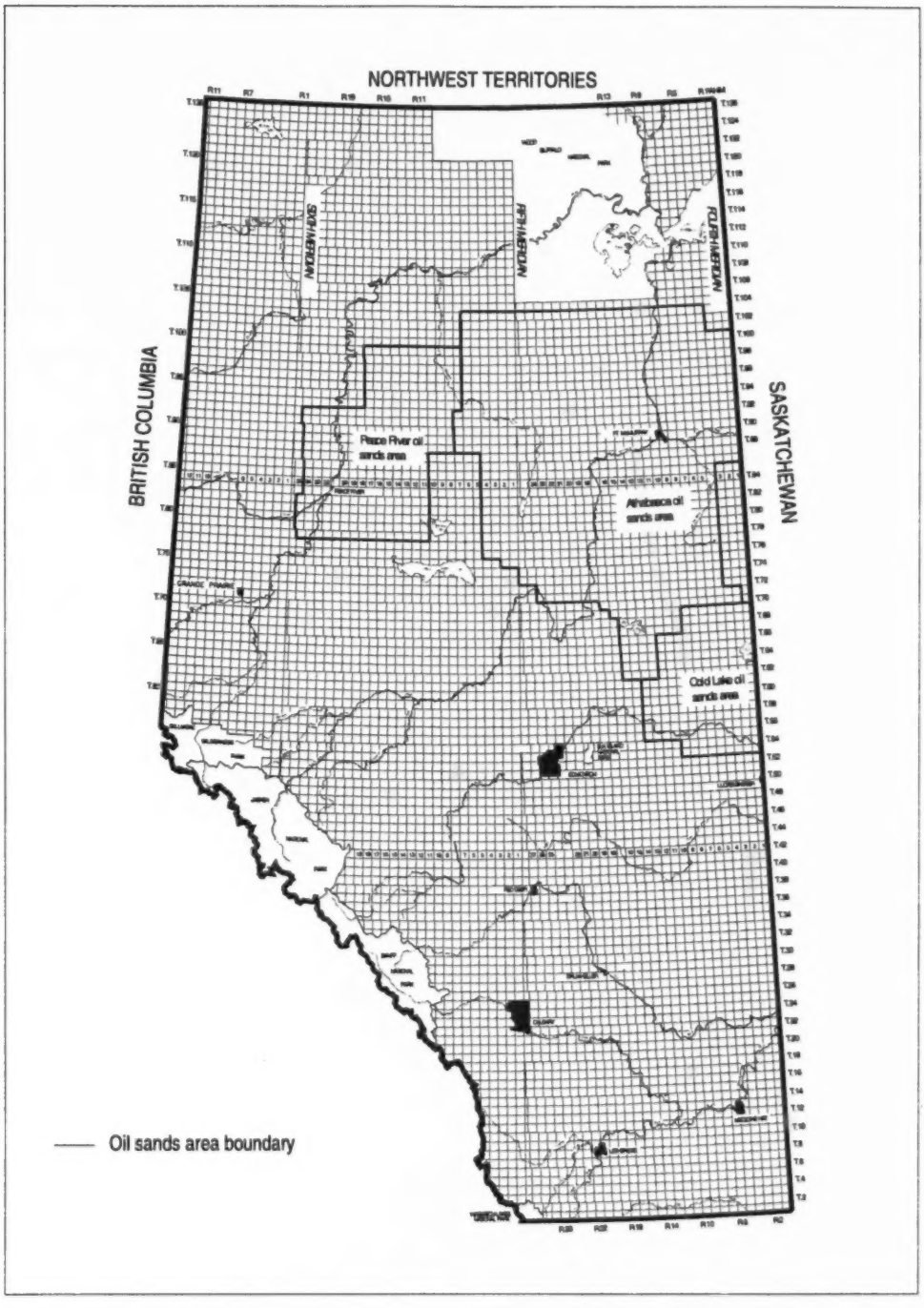

Figure 1. Oil sands area boundary

Any plug may be staged; however, the break between stages in a multistage plug must occur within a zone and must not occur at a zone top.

There is no maximum distance between plugs as long as the pressure from the zone being isolated does not exceed the fracture pressure of the interval left open above it.

The top plug must extend a minimum of 15 vertical metres above the casing shoe of the deepest casing set.

In a well in which intermediate casing has been set but has not been cemented full length, the uncemented interval must be evaluated as follows:

- If nonsaline groundwater has not been covered by surface casing and the intermediate casing cement top is below the BGWP, remedial cementing must be conducted to cover and/or isolate nonsaline groundwater.
- If there are porous intervals not covered by the intermediate casing's primary cement, remedial cementing must be conducted to cover and/or isolate the interval.

Following completion of the plugging program, the wellbore must be filled with nonsaline water.

Examples of plugging programs are provided in Figures 2a, b, c, and d.

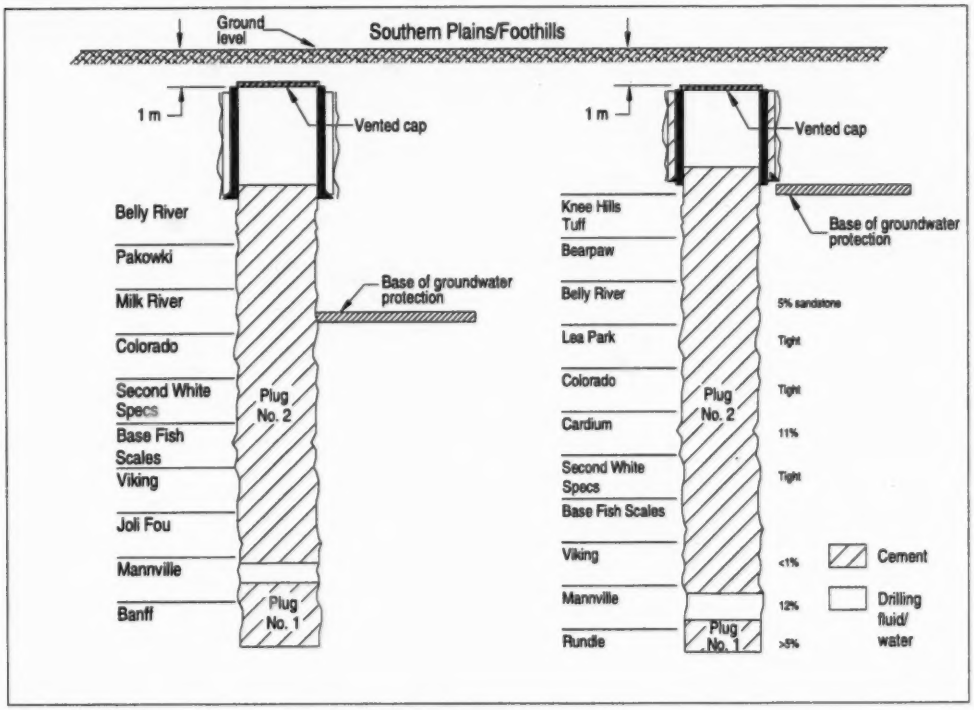

Figure 2a. Plug placement examples for Southern Plains/Foothills

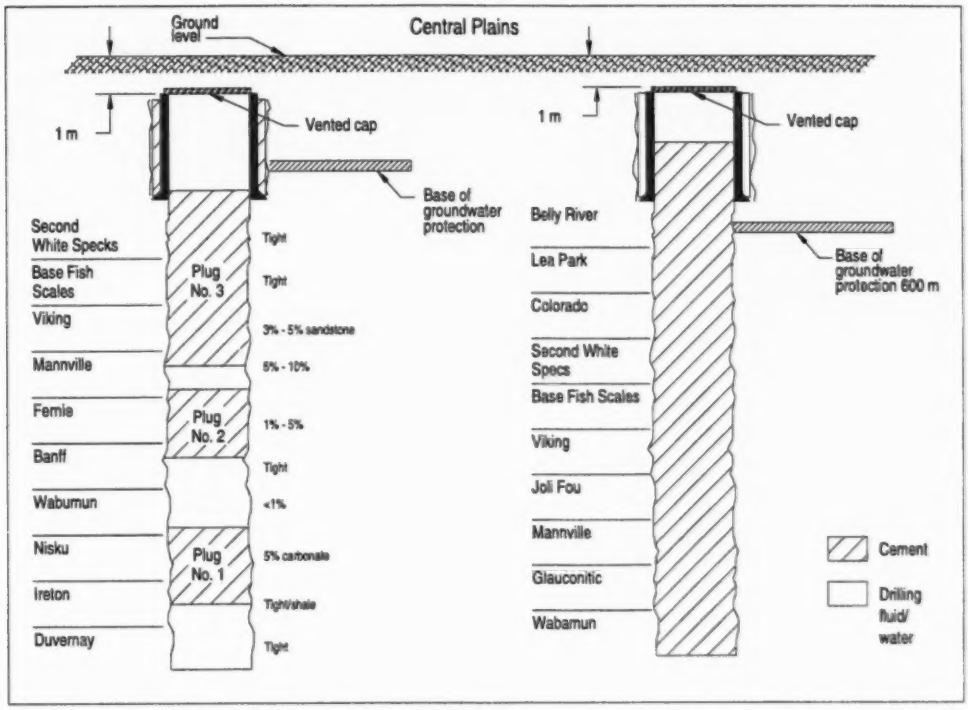

Figure 2b. Plug placement examples for Central Plains

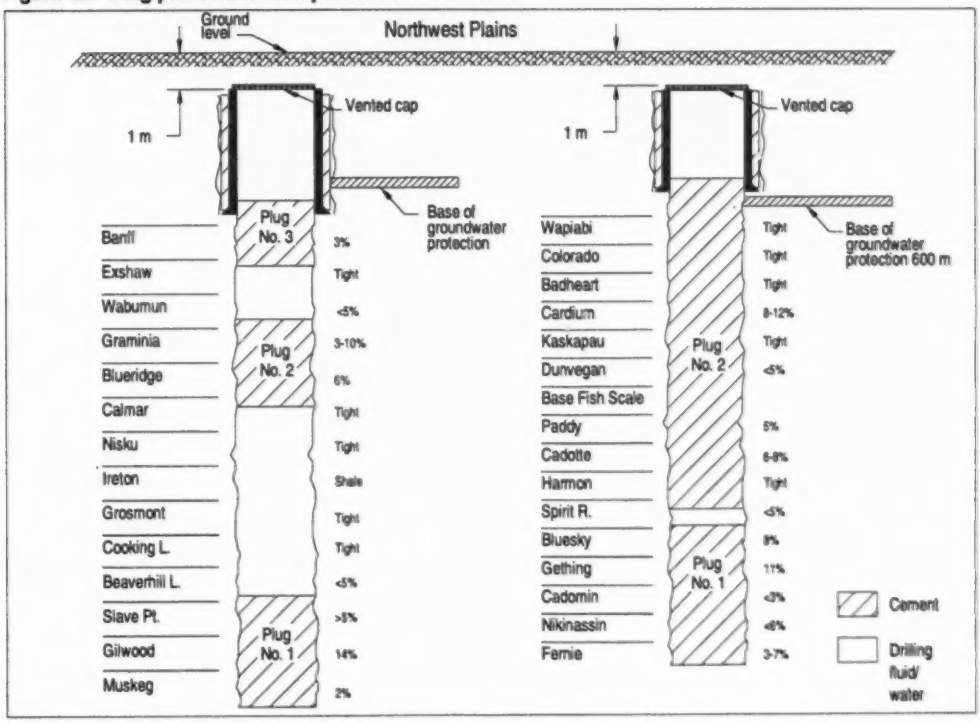

Figure 2c. Plug placement examples for Northwest Plains

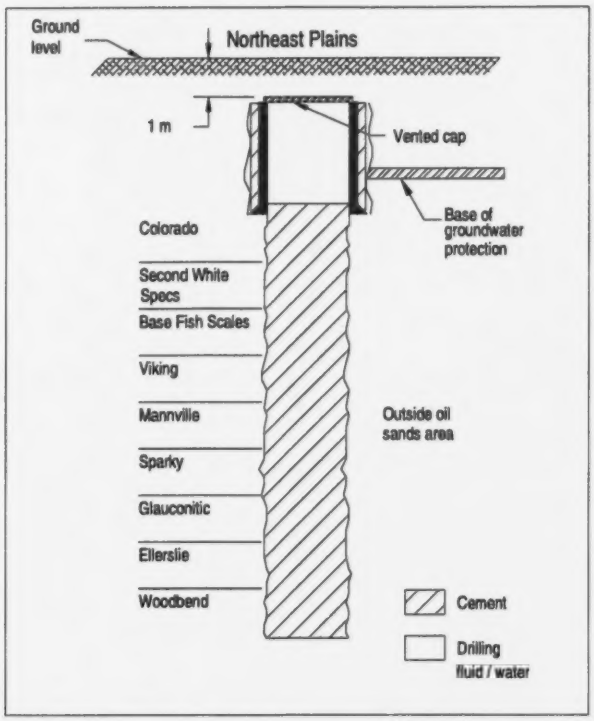

Figure 2d. Plug placement example for Northeast Plains

4.2 Open-Hole Abandonment of Wells That Have Penetrated Oil Sands Zones

For wells that are in an oil sands area (see Figure 1 and tables below) and have penetrated oil sands zones, thermal cement must be used for the entire length of the plug that is across the oil sands zone(s). Thermal cement is a blend that after curing for 48 hours has a minimum compressive strength of 3500 kPa at temperatures up to 360°C.

Cold Lake Oil Sands Area

Township	Ranges
053 - 054	01W4M to 09W4M
055 - 061	01W4M to 13W4M
062 - 066	01W4M to 11W4M
067 - 069	01W4M to 08W4M

Athabasca Oil Sands Area

Township	Ranges
062 - 066	12W4M to 15W4M
067 - 068	09W4M to 15W4M
069	09W4M to 16W4M
070	02W4M to 17W4M
071	02W4M to 24W4M
072	04W4M to 24W4M
073 - 074	04W4M to 26W4M
075	04W4M to 02W5M
076 - 085	04W4M to 04W5M
086 - 087	01W4M to 04W5M
088 - 092	01W4M to 07W5M
093 - 100	01W4M to 06W5M
101 - 103	04W4M to 06W5M

Peace River Oil Sands Area

Township	Ranges
78 - 82	11W5M to 25W5M
83 - 87	11W5M to 24W5M
88 - 92	08W4M to 24W5M
93 - 99	07W4M to 17W5M

4.3 Wells in the Cold Lake/Athabasca Oil Sands Area

A thermal plug must be set from the well's total depth to a minimum of 15 vertical metres above the top of the Grand Rapids Formation.

All zones above the top of the Mannville Group (or equivalent) must be covered with a plug that is placed in one or more stages.

For intervals that are not across an oil sands zone, the use of fillers and/or additives in the cement is acceptable if the compressive strength of the mixture is at least 3500 kPa after curing for 48 hours.

Any plug may be staged; however, the break between stages in a multistage plug must occur within a zone and must not occur at a zone top.

The top plug must extend a minimum of 15 vertical metres above the casing shoe of the deepest casing set.

In a well in which intermediate casing has been set but has not been cemented full length, the uncemented interval must be evaluated as follows:

- If nonsaline groundwater has not been covered by surface casing and the intermediate casing cement top is below the BGWP, remedial cementing must be conducted to cover and/or isolate nonsaline groundwater.
- If there are porous intervals not covered by the intermediate casing's primary cement, remedial cementing must be conducted to cover/isolate the interval.

Following completion of the plugging program, the wellbore must be filled with nonsaline water.

An example plugging program is provided in Figure 3.

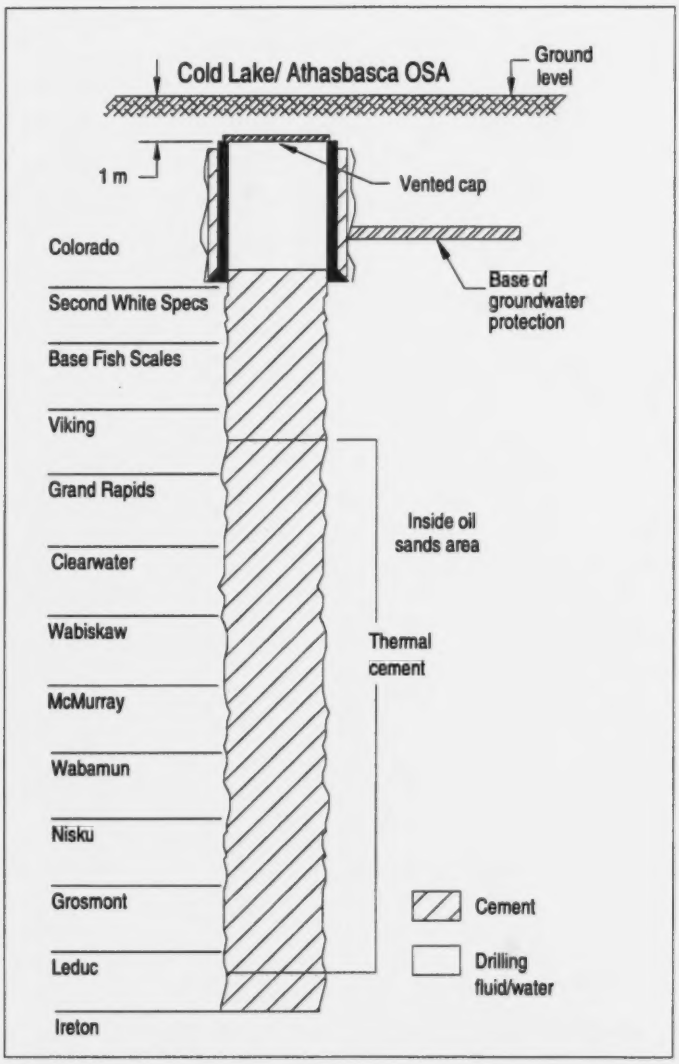

Figure 3. Plug placement example for Cold Lake/Athabasca Oil Sands Area

4.4 Wells in the Peace River Oil Sands Area

All zones above the top of the Spirit River Group must be covered with a plug that is placed in one or more stages. This plug must extend a minimum of 15 vertical metres below the top of the Spirit River Group.

Licensees must use the logs from the well to determine the exact plug placement for coverage and/or isolation of porous zones below the top of the Spirit River Group.

For intervals that are not across oil sands zones, the use of fillers and/or additives in the cement is acceptable if the compressive strength of the mixture is at least 3500 kPa after curing for 48 hours.

A thermal plug must be set that extends from a minimum of 15 vertical metres below the base of any oil sands zone to a minimum of 15 vertical metres above the top of the oil sands zone.

All plugs run at a depth less than 1500 m TVD must be a minimum length of 30 vertical metres, and they must extend a minimum of 15 vertical metres below and a minimum of 15 vertical metres above the zone being covered.

All plugs run at a depth greater than 1500 m TVD must be a minimum length of 60 vertical metres, and they must extend a minimum of 30 vertical metres below and a minimum of 30 vertical metres above the zone being covered.

A plug may extend over more than one zone.

Any plug may be staged; however, the break between stages in a multistage plug must occur within a zone and must not occur at a zone top.

There is no maximum distance between plugs as long as the pressure from the zone being isolated does not exceed the fracture pressure of the interval left open above it.

The top plug must extend a minimum of 15 vertical metres above the casing shoe of the deepest casing set.

In a well in which intermediate casing has been set but has not been cemented full length, the uncemented interval must be evaluated as follows:

- If nonsaline groundwater has not been covered by surface casing and the intermediate casing cement top is below the BGWP, remedial cementing must be conducted to cover and/or isolate nonsaline groundwater.
- If there are porous intervals not covered by the intermediate casing's primary cement, remedial cementing must be conducted to cover/isolate the interval.

Following completion of the plugging program, the wellbore must be filled with nonsaline water.

An example of a plugging program is provided in Figure 4.

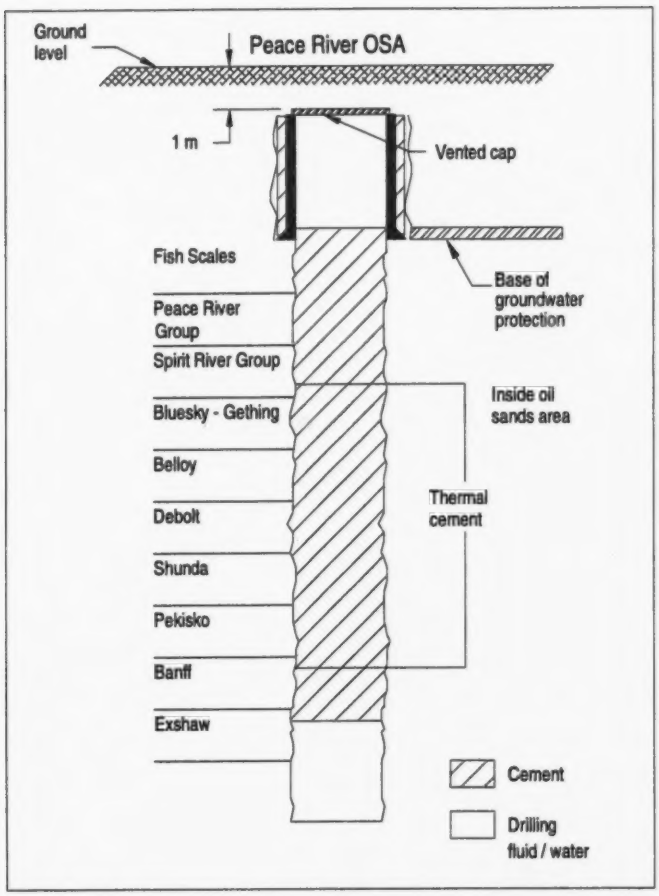

Figure 4. Plug placement example for Peace River Oil Sands Area

4.5 Confirming Plug Placement

The licensee must confirm the location of all plugs using one of the approved methods described in Section 6. The only time a plug location does not have to be confirmed is if

- one stage of a multistage plug is placed, provided there is no loss of circulation;
- continuous cement is run from total depth to surface in one or more stages, provided there was no loss of circulation; or
- the top plug is placed, providing it is run to surface.

Plugs that are too low or too high or were misplaced are unacceptable (see Figure 5).

The licensee must correct the misplaced plug and must confirm the new location.

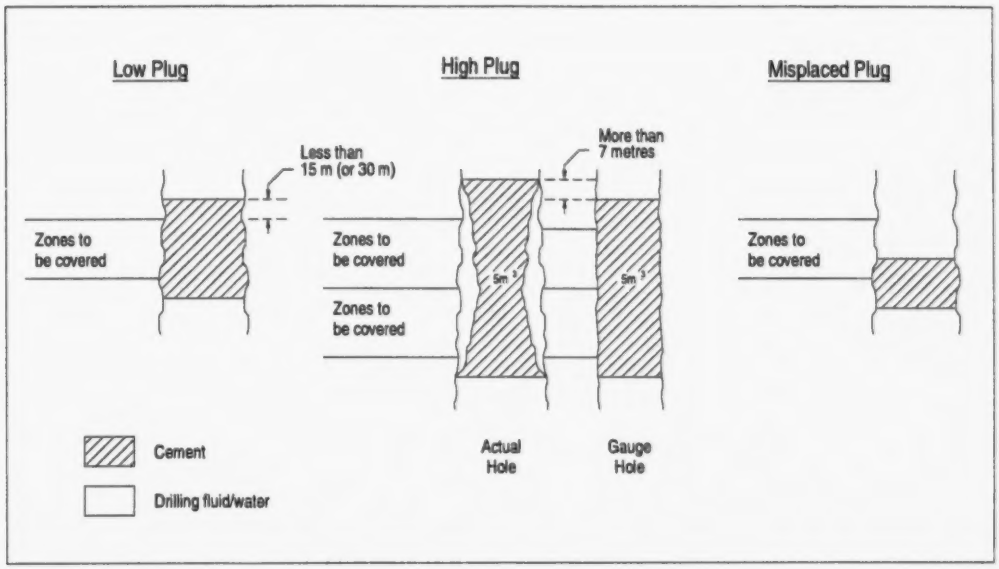

Figure 5. Unacceptable plugs

Regarding Figure 5:

Plug is too low:

- For zones at a depth less than 1500 m TVD, a low plug is any plug with a top less than 15 vertical metres above the zone it was intended to cover.
- For zones at a depth greater than 1500 m TVD, a low plug is any plug with a top less than 30 vertical metres above the zone it was intended to cover.

Action required: Low plugs must be built up and then the new location must be confirmed.

Plug is too high: A plug that is located more than 7 vertical metres above its theoretical top is considered "high." To calculate a plug's theoretical top, use the formula

Actual cement volume (m^3)/gauge hole volume (m^3/m) = x m

Drill pipe setting depth (m) – x m = Theoretical top

Action required: High plugs must be circulated or drilled out. The plug must be rerun and its location confirmed.

Plug is misplaced: The plug was positioned in such a way that it did not cover the zone(s) it was intended to cover.

Action required: Depending on its position, a misplaced plug may first have to be circulated or drilled out. The plug must be rerun and its location confirmed.

4.6 Oil Sands Evaluation Wells and Test Hole Wells

Oil sands evaluation and test hole wells (as identified by "OV" and "TH" respectively on the licence's Lahee Classification) have specific abandonment requirements. These wells are drilled for core samples only and are not intended to be completed.

Downhole abandonment operations on oil sands evaluation and test hole wells in the surface mineable areas must be completed within 30 days after drilling has finished.

Downhole abandonment operations on oil sands evaluation and test hole wells that are outside of the surface mineable areas must be completed prior to rig release.

Oil sands evaluation and test hole wells that encounter an oil sands zone and/or are within a designated oil sands area must be filled with thermal cement from final total depth to surface.

Test hole wells that are drilled outside a designated oil sands area and do not encounter an oils sands zone must be filled with cement that has a final compressive strength of at least 3500 kPa after curing for 48 hours from final total depth to surface.

Any drop in cement due to pipe displacement must be replaced by an equivalent volume of nonsaline water. If the calculated and actual volumes required to fill the hole coincide, fluid level testing is not required.

Surface abandonment operations must be completed immediately after downhole operations.

Oil sands evaluation and test hole well abandonments are considered routine and must be reported within 30 days of completing the surface abandonment.

5 Cased-Hole Abandonment Requirements

In a cased-hole abandonment, the licensee must abandon each completed pool separately and cover all nonsaline groundwater with cement.

The abandonment program for a cased-hole well will depend on whether

- the well was completed,
- the well penetrated any oil sands zones, and
- the well has been completed in a interval that is classified as "level A."

For the purpose of this directive, level-A intervals are intervals that

- have been used for disposal of 1a or 1b fluids,
- have been used for injection of acid gas,
- have a hydrogen sulphide (H_2S) concentration in excess of 15 per cent, or
- have been designated as critical sour.

This evaluation is done on a well (not a pool) basis.

Note that it is advisable to perform testing prior to beginning downhole abandonment operations to avoid having to reenter the well to correct a wellbore problem. Refer to Section 7.

5.1 Cement Evaluation

The licensee must review the existing cement behind the casing string(s) of a well before beginning abandonment operations.

5.1.1 Cement Top Determination

The cement top can be determined by available locating log data, theoretical calculations, or a cement evaluation log. Confirmation of cement returns to surface in the drilling tour sheets during primary cementing is also acceptable for confirming cement coverage to surface.

A cement evaluation log must be run if

- theoretical calculations (using an excess of 20 per cent) indicate that the cement top does not extend a minimum of 15 vertical metres above the uppermost porous intervals, or
- there is a surface casing vent flow and/or gas migration issue present.

5.1.2 Identification of Porous Intervals

The licensee must identify porous zones (see glossary) and determine that hydraulic isolation exists between zones.

5.1.3 Remedial Cementing

If there are porous zones that are not isolated from each other, the licensee must perforate the casing and circulate cement to surface. If it is not possible to achieve circulation, cement squeeze(s) must be conducted to ensure isolation.

For remediation of surface casing vent flows or gas migration, see *ID 2003-01*.

5.2 Use of Inhibitor

The casing must be filled with nonsaline water from the uppermost abandoned zone (that is below the BGWP) to surface.

Inhibitor must not be used inside the casing over intervals that are above the BGWP.

For intervals below the BGWP that are isolated from the BGWP by an approved zonal abandonment method, the casing must be filled with either noncorrosive fluid or nonsaline water

5.3 Wells Not Penetrating Oil Sands Zones

Requirements for abandonment operations on cased-hole wells that **do not** penetrate oil sands zones are as follows.

5.3.1 Noncompleted Wells

Noncompleted wells (without liners) do not require additional cement plugs to be run if the existing casing string is pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

Noncompleted wells must be filled with nonsaline water.

5.3.2 Wells With a Cemented Liner

The completed interval must be abandoned in accordance with the requirements set out in Sections 5.3.5, 5.3.6, or 5.3.7. Following abandonment of the completed interval(s), the licensee must use one of the following options for abandoning a liner top in a well with a cemented liner.

Option 1—Setting a Permanent Bridge Plug

A permanent bridge plug must be set within 15 m above the liner top. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with either a minimum of 8 vertical metres of class "G" cement or with a minimum of 3 vertical metres of resin-based, low-permeability gypsum cement.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2—Setting a Cement Plug

A cement plug must be set across the liner top. This plug must extend from a minimum of 15 vertical metres below the liner top to a minimum of 15 vertical metres above the liner top. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

5.3.3 Wells With an Uncemented Liner

To abandon a well with an uncemented liner across more than one zone, the zones behind the liner must be evaluated for porosity and a cement squeeze(s) must be conducted to ensure isolation between the porous zones.

Once the liner has been cemented, the requirements set out for abandonment of wells with a cemented liner (above) must be followed.

5.3.4 Wells With Casing Patching, Casing Failures, and Previously Cement Squeezed Intervals

For non-level A intervals, the licensee must use one of the following options for abandoning casing patches, casing failures (within one zone), and previously cement squeezed intervals (within one zone that have been drilled out). For abandonment of previously cement squeezed intervals that have been drilled out and are over more than one zone, each zone must be isolated by one of the methods below. For abandonment of casing failures that occur over more than one zone, a cement squeeze must be conducted as set out below in option 3.

Casing patches, casing failures, and previously cement squeezed intervals (that have been drilled out) that are over a level-A interval must be abandoned in accordance with Section 5.3.5.1.

Option 1—Setting a Permanent Bridge Plug

A permanent bridge plug must be set within 15 m above the interval. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with either a minimum of 8 vertical metres of class "G" cement or with a minimum of 3 vertical metres of resin-based, low-permeability gypsum cement.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2—Setting a Cement Plug/Squeezing Cement

A cement plug must be set that extends a minimum of 15 vertical metres below the bottom of the interval to a minimum 15 vertical metres above the top of the interval. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested to 7000 kPa for 10 minutes.

If the licensee elects to apply a squeeze pressure to the cement, the ERCB recommends following the criteria set out in Option 2 of Section 5.3.5.1 (minimum cement volumes, final squeeze pressures, etc.).

5.3.5 Zonal Abandonment Within a Completed Well

5.3.5.1 Level-A Intervals

The licensee must use one of the following options for abandoning level-A intervals within a completed well.

Option 1—Setting a Cement Retainer

A cement retainer must be set within 15 m above the perforations or the single-zone open-hole section.

- The retainer must be pressure tested to a stabilized pressure that equates to a minimum differential pressure of 7000 kPa for 10 minutes.
- A cement squeeze must be conducted through the retainer.
- The minimum cement volume must equal the casing volume from the bottom of the retainer to the bottom perforation (or bottom of the open-hole section) plus 0.5 m^3.
- The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned.
- The retainer must be capped with class "G" cement that is circulated in place and
  - is a minimum of 30 vertical metres in length,
  - extends a minimum of 30 vertical metres above the formation top, and
  - has a minimum volume of 1 m^3.

If the retainer is drilled out, following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85 per cent of the current or expected reservoir pressure of the perforations that will be open to the wellbore.

At the time of well abandonment, the squeezed interval(s) must be abandoned in accordance with Section 5.3.5.1.

Option 2—Squeezing Cement

A cement squeeze must be conducted into the perforations or the single-zone open-hole section.

The plug must

- be circulated in place,
- have a minimum volume of 1 m^3, and
- extend from a minimum of 15 vertical metres below the completion or total depth, whichever is shallower, to a minimum of 30 vertical metres above the formation top.

The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

If this plug is to be drilled out, following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85 per cent of the current or expected reservoir pressure of the perforations that will be open to the wellbore. At the time of well abandonment, the squeezed intervals must be abandoned in accordance with Section 5.3.5.1.

Option 3—Setting a Permanent Bridge Plug

Abandonment of a Level-A interval by this method will require nonroutine approval from the ERCB's Well Operations Group.

A bond log must be run over the interval where a permanent bridge plug will be set to a minimum of 60 m above the formation top. The bond log and the log interpretation must be submitted to the ERCB's Well Operations Group for approval. If zonal isolation is confirmed, approval may be granted to set a permanent bridge plug within 15 m above the perforation or the single-zone open-hole section. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with class "G" cement that is circulated in place and

- is a minimum of 60 vertical metres in length,
- extends a minimum of 60 vertical metres above the formation top, and
- has a minimum volume of 1 m^3.

If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

5.3.5.2 Non-Level-A Intervals

The licensee must use one of the following options for abandoning non-level-A intervals within a completed well.

Option 1—Setting a Permanent Bridge Plug

A permanent bridge plug must be set within 15 m above the perforation or the single-zone open-hole section. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with either a minimum of 8 vertical metres of class "G" cement or with a minimum of 3 vertical metres of resin-based, low-permeability gypsum cement.

If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2—Setting a Cement Retainer

A cement retainer must be set within 15 m above the perforations or the single-zone open-hole section. The retainer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. A cement squeeze must be conducted into the perforations or the single-zone open-hole section. The retainer must be capped with a minimum of 8 vertical metres of class "G" cement. The ERCB recommends following the criteria set out in Option 1 of Section 5.3.5.1 (minimum cement volumes, final squeeze pressures, etc.).

If the retainer is drilled out, following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85 per cent of the current or expected reservoir pressure of the perforations that will be open to the wellbore.

At the time of well abandonment, the squeezed interval(s) must be abandoned in accordance with Section 5.3.4.

Option 3—Setting a Plug in a Permanent Packer

A plug must be set in a permanent packer within 15 m above the perforation or the single-zone open-hole section. The plug and packer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug and packer must be capped with either a minimum of 8 vertical metres of class "G" cement or a minimum of 3 vertical metres of resin-based, low-permeability gypsum cement.

If more than one year has elapsed from the setting and pressure testing of the plug and packer prior to capping with cement, the plug and packer must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

Option 4—Setting a Cement Plug/Squeezing Cement

A cement plug must be set across the perforations or the single-zone open-hole section. The plug must extend a minimum of 15 vertical metres below either the completed interval or the plug-back total depth, whichever is shallower, to a minimum of 15 vertical metres above the top of the completed interval. It is acceptable to run a continuous cement plug across multiple completed zones. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. If the licensee elects to apply a squeeze pressure to the cement, the ERCB recommends following the criteria set out in Option 2 of Section 5.3.5.1 (minimum cement volumes, final squeeze pressures, etc.).

If the cement plug is to be drilled out, a cement squeeze must be conducted. Following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85 per cent of the current or expected reservoir pressure of the perforations that will be open to the wellbore. At the time of well abandonment, the squeezed interval must be abandoned in accordance with Section 5.3.4.

5.3.6 Completed Horizontal Wells in a Single Formation

5.3.6.1 Level-A Intervals

Zonal abandonment of a level-A interval with a horizontal open-hole interval that penetrates one formation must be abandoned with one of the following options.

Option 1—Setting a Cement Retainer

A cement retainer must be set within 15 vertical metres above the top of the formation in which the horizontal zone is completed.

- The retainer must be pressure tested to a stabilized pressure that equates to a minimum differential pressure of 7000 kPa for 10 minutes.
- A cement squeeze must be conducted through the retainer.
  - The minimum cement volume must equal the casing volume from the bottom of the retainer to the measured total depth of the well plus 0.5 m^3.

- The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned.

- The retainer must be capped with class "G" cement that is circulated in place and
  - is a minimum of 30 vertical metres in length, and
  - has a minimum volume of 1 m^3.

Option 2—Squeezing Cement

A cement squeeze must be conducted into the perforations or the single-zone open-hole section.

The plug must

- be circulated in place,
- have a minimum volume of 1 m^3, and
- extend from at or below the formation top to a minimum of 30 vertical metres above the formation top.

The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

Option 3—Setting a Permanent Bridge Plug

Abandonment of a Level-A interval by this method will require nonroutine approval from the ERCB's Well Operations Group.

A bond log must be run over the interval where a permanent bridge plug will be set to a minimum of 60 m above the formation top. The bond log and the log interpretation must be submitted to the ERCB's Well Operations Group for approval. If zonal isolation is confirmed, approval may be granted to set a permanent bridge within 15 vertical metres above the top of the formation in which the horizontal zone is completed. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with class "G" cement that is circulated in place and

- is a minimum of 60 vertical metres in length,
- is a minimum of 60 vertical metres above the formation top, and
- has a minimum volume of 1 m^3.

If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

5.3.6.2 Non-Level-A Intervals

Zonal abandonment of a non-level-A interval with a horizontal open-hole interval that penetrates one formation must be abandoned with one of the following options:

Option 1—Setting a Permanent Bridge Plug

A permanent bridge plug must be set within 15 vertical metres above the top of the formation in which the horizontal zone is completed. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with either a minimum of 8 vertical metres of class "G" cement or a minimum of 3 vertical metres of resin-based, low-permeability gypsum cement.

If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2—Setting a Cement Retainer

A cement retainer must be set within 15 vertical metres above the top of the formation in which the horizontal zone is completed. The retainer must be pressure tested to a stabilized pressure of 7000 kPa for 10 minutes. A cement squeeze must be conducted through the retainer. The retainer must be capped with a minimum of 8 vertical metres of class "G" cement. The ERCB recommends following the criteria set out in Option 1 of Section 5.3.6.1 (minimum cement volumes, final squeeze pressures, etc.).

Option 3— Setting a Cement Plug/Squeezing Cement

A cement squeeze must be conducted into the open-hole interval. The plug must extend from at or below the formation top to a minimum of 15 vertical metres above the formation top. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. If the licensee elects to apply a squeeze pressure to the cement, the ERCB recommends following the criteria set out in Option 2 of Section 5.3.6.1 (minimum cement volumes, final squeeze pressures, etc.).

5.3.7 Completed Horizontal Wells Across Multiple Formations

For a horizontal open-hole interval that penetrates multiple formations, each porous formation must have a cement plug set in the open-hole section to either cover or isolate it from different porous formations. A minimum 30 vertical metre cement plug is required, extending either a minimum of 15 vertical metres below the formation or the plug-back total depth, whichever is shallower, to a minimum of 15 vertical metres above the porous formation. The location of the plug must be confirmed by one of the approved methods described in Section 6.

If **any** of the horizontal intervals is a level-A interval, the uppermost interval must be abandoned in accordance with Section 5.3.6.1.

5.4 Wells Penetrating Oil Sands Zones

Requirements for abandonment operations on cased-hole wells that are in an oil sands area (see Figure 1) and penetrate oil sands zones are as follows.

5.4.1 Thermal Cement

Thermal cement must be used when abandoning wellbores that penetrate oil sands. Thermal cement is a blend that after curing for 48 hours has a minimum compressive strength of 3500 kPa at temperatures up to 360°C.

5.4.2 Noncompleted Wells

The casing string must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

All noncompleted oil sands zones must have a thermal cement plug run across the oil sands formation. The plug must extend from a minimum of 15 vertical metres below the formation or the plug-back total depth, whichever is shallower, to a minimum of 15 vertical metres above the top of the formation. This plug may be combined into a longer plug to cover two or more uncompleted oil sands zones. Nonsaline water must be used between plugs.

The location of suspended cement plugs must be confirmed by one of the approved methods described in Section 6. The location of plugs that are run from plug back total depth (PBTD) to surface does not need to be confirmed.

Noncompleted wells with liners must have the liner abandoned in accordance with Section 5.4.3 or 5.4.4.

5.4.3 Wells With a Cemented Liner

The completed interval must be abandoned in accordance with the requirements set out below for completed, open-hole, or horizontal intervals (see Section 5.4.6, 5.4.7, or 5.4.8). Following abandonment of the completed interval(s), the licensee must use one of the following options for abandoning a liner top in a well with a cemented liner.

Option 1—Setting a Permanent Bridge Plug

A permanent bridge plug must be set within 15 m above the liner top. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with a minimum of 8 vertical metres of thermal cement.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2—Setting a Cement Plug

A thermal cement plug must be set across the liner top. This plug must extend from a minimum of 15 vertical metres below the liner top to a minimum of 15 vertical metres above the liner top. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

5.4.4 Wells With an Uncemented Liner

To abandon a well with an uncemented liner across more than one zone, the zones behind the liner must be evaluated for porosity, and thermal cement squeeze(s) must be conducted to ensure isolation between the porous zones.

Once the liner has been cemented, the requirements set out for abandonment of wells with a cemented liner (Section 5.4.3) must be followed.

5.4.5 Wells with Casing Patching, Casing Failures, and Previously Cement Squeezed Intervals

For non-level A intervals, the licensee must use one of the following options for abandoning casing patches, casing failures within one zone, and previously cement squeezed intervals within one zone that have been drilled out. For abandonment of previously cement squeezed intervals that have been drilled out and are over more than one zone, each zone must be isolated by one of the methods below. For abandonment of casing failures that occur over more than one zone, a cement squeeze must be conducted as set out below in option 3.

Casing patches, casing failures, and previously cement squeezed intervals (that have been drilled out) that are over a level-A interval must be abandoned in accordance with Section 5.4.6.1.

Option 1—Setting a Permanent Bridge Plug

A permanent bridge plug must be set within 15 m above the interval. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with a minimum of 8 vertical metres of thermal cement.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2—Setting a Cement Plug /Squeezing Cement

A thermal cement plug must be set that extends a minimum of 15 vertical metres below the bottom of the interval to a minimum 15 vertical metres above the top of the interval. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. If the licensee elects to apply a squeeze pressure to the cement, the ERCB recommends following the criteria set out in Option 2 of Section 5.4.6.1 (minimum cement volumes, final squeeze pressures, etc.).

5.4.6 Completed Wells

The licensee must review the well logs to determine which oil sands zones have been penetrated by the well.

Oil sands zones that have been penetrated but not completed must have a thermal cement plug run in accordance with Section 5.4.2.

Each oil sands zone that is completed must be abandoned using one of the following options.

5.4.6.1 Level-A Intervals

The licensee must use one of the following options for abandoning level-A intervals within a completed well.

Option 1—Setting a Cement Retainer

A cement retainer must be set within 15 m above the perforations or the single-zone open-hole section.

- The retainer must be pressure tested to a stabilized pressure that equates to a minimum differential pressure of 7000 kPa for 10 minutes.
- A thermal cement squeeze must be conducted through the retainer.

- The minimum cement volume must equal the casing volume from the bottom of the retainer to the bottom perforation (or bottom of the open-hole section) plus 0.5 m^3.
- The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned.
- The retainer must be capped with thermal cement that is circulated in place and
  - is a minimum of 30 vertical metres in length,
  - extends a minimum of 30 vertical metres above the formation top, and
  - has a minimum volume of 1 m^3.

If the retainer is drilled out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85 per cent of the current or expected reservoir pressure of the perforations that will be open to the wellbore.

At the time of well abandonment, the squeezed interval(s) must be abandoned in accordance with Section 5.4.6.1.

Option 2—Squeezing Cement

A thermal cement squeeze must be conducted into the perforations or the single-zone open-hole section.

The plug must

- be circulated in place,
- have a minimum volume of 1 m^3, and
- extend from a minimum of 15 vertical metres below the completion or total depth, whichever is shallower, to a minimum of 30 vertical metres above the formation top.

The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

If this plug is to be drilled out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85 per cent of the current or expected reservoir pressure of the perforations that will be open to the wellbore. At the time of well abandonment, the squeezed intervals must be abandoned in accordance with Section 5.3.5.1.

Option 3—Setting a Permanent Bridge Plug

Abandonment of a Level-A interval by this method will require nonroutine approval from the ERCB's Well Operations Group.

A bond log must be run over the interval where a permanent bridge plug will be set to a minimum of 60 m above the formation top. The bond log and the log interpretation must be submitted to the ERCB's Well Operations Group for approval. If zonal isolation is confirmed, approval may be granted to set a permanent bridge plug within 15 m above the perforation or the single-zone open-hole section. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with thermal cement that is circulated in place and

- is a minimum of 60 vertical metres in length,

- extends a minimum of 60 vertical metres above the formation top, and
- has a minimum volume of 1 m^3.

If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

5.4.6.2 Non-Level-A Intervals

The licensee must use one of the following options for abandoning non-level-A intervals within a completed well.

Option 1—Setting a Permanent Bridge Plug

A permanent bridge plug must be set within 15 m above the perforations or the single-zone open-hole section. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with a minimum of 8 vertical metres of thermal cement. The cement top must extend a minimum of 15 vertical metres above the formation top.

If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2—Setting a Cement Retainer

A cement retainer must be set within 15 m above the perforations or the single-zone open-hole section. The retainer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. A thermal cement squeeze must be conducted into the perforations or the single-zone open-hole section. The retainer must be capped with a minimum of 8 vertical metres of thermal cement. The cement top must extend a minimum of 15 vertical metres above the formation top. The ERCB recommends following the criteria set out in Option 1 of Section 5.4.6.1 (minimum cement volumes, final squeeze pressures, etc.).

If this plug is to be drilled out, following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85 per cent of the current or expected reservoir pressure of the perforations that will be open to the wellbore. At the time of well abandonment, the squeezed intervals must be abandoned in accordance with Section 5.4.5.

Option 3—Setting a Plug in a Permanent Packer

A plug must be set in a permanent packer within 15 m above the perforation or the single-zone open-hole section. The plug and packer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with a minimum of 8 vertical metres of thermal cement. The cement top must extend a minimum of 15 vertical metres above the formation top.

If more than one year has elapsed from the setting and pressure testing of the plug and packer prior to capping with cement, the plug and packer must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

Option 4—Setting a Cement Plug/Squeezing Cement

A thermal cement plug must be set across the perforations or the single-zone open-hole section. The plug must extend a minimum of 15 vertical metres below either the completed interval or the plug-back total depth, whichever is shallower, to a minimum of 15 vertical metres above the top of the formation. It is acceptable to run a continuous thermal cement plug across multiple zones. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. If the licensee elects to apply a squeeze pressure to the cement, the ERCB recommends following the criteria set out in Option 2 of Section 5.4.6.1 (minimum cement volumes, final squeeze pressures, etc.).

If the cement plug is to be drilled out, a cement squeeze must be conducted. Following drill-out, the squeezed interval must be pressure tested for 10 minutes at a stabilized pressure equal to the greater of 7000 kPa or 85 per cent of the current or expected reservoir pressure of the perforations that will be open to the wellbore. At the time of well abandonment, the squeezed interval must be abandoned in accordance with Section 5.4.5.

5.4.7 Completed Horizontal Wells in a Single Formation

5.4.7.1 Level-A Intervals

Zonal abandonment of a level-A interval with a horizontal open-hole interval that penetrates one formation must be abandoned with one of the following options.

Option 1—Setting a Cement Retainer

A cement retainer must be set within 15 vertical metres above the top of the formation in which the horizontal zone is completed.

- The retainer must be pressure tested to a stabilized pressure that equates to a minimum differential pressure of 7000 kPa for 10 minutes.
- A thermal cement squeeze must be conducted through the retainer.
  - The minimum cement volume must equal the casing volume from the bottom of the retainer to the measured total depth of the well plus 0.5 m^3.
  - The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned.
- The retainer must be capped with thermal cement that is circulated in place and
  - is a minimum of 30 vertical metres in length, and
  - has a minimum volume of 1 m^3.

Option 2—Squeezing Cement

A thermal cement squeeze must be conducted into the perforations or the single-zone open-hole section.

The plug must

- be circulated in place,
- have a minimum volume of 1 m^3, and

- extend from at or below the formation top to a minimum of 30 vertical metres above the formation top.

The final squeeze pressure must be a minimum of 7000 kPa above the current reservoir pressure of the zone being abandoned. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

Option 3—Setting a Permanent Bridge Plug

Abandonment of a Level-A interval by this method will require nonroutine approval from the ERCB's Well Operations Group.

A bond log must be run over the interval where a permanent bridge plug will be set to a minimum of 60 m above the formation top. The bond log and the log interpretation must be submitted to the ERCB's Well Operations Group for approval. If zonal isolation is confirmed, approval may be granted to set a permanent bridge within 15 vertical metres above the top of the formation in which the horizontal zone is completed. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with thermal cement that is circulated in place and

- is a minimum of 60 vertical metres in length,
- is a minimum of 60 vertical metres above the formation top, and
- has a minimum volume of 1 m^3.

If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

5.4.7.2 Non-Level-A Intervals

Zonal abandonment of a non-level-A horizontal open-hole interval that penetrates one formation must be abandoned with one of the following options.

Option 1—Setting a Permanent Bridge Plug

A permanent bridge plug must be set within 15 vertical metres above the top of the formation in which the horizontal zone is completed. Once the bridge plug has been set, it must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The plug must be capped with a minimum of 8 vertical metres of thermal cement. The cement top must extend a minimum of 15 vertical metres above the formation top.

If more than one year has elapsed from the setting and pressure testing of the bridge plug prior to capping with cement, the bridge plug must be pressure tested again at a stabilized pressure of 7000 kPa for 10 minutes.

A retainer that has not been activated can be substituted for the permanent bridge plug.

Option 2—Setting a Cement Retainer

A cement retainer must be set within 15 vertical metres above the top of the formation in which the horizontal zone is completed. The retainer must be pressure tested to a stabilized pressure of 7000 kPa for 10 minutes. A thermal cement squeeze must be conducted through the retainer. The retainer must be capped with a minimum of 8 vertical metres of thermal

cement. The cement top must extend a minimum of 15 vertical metres above the formation top. The ERCB recommends following the criteria set out in Option 1 of Section 5.4.7.1 (minimum cement volumes, final squeeze pressures, etc.).

Option 3— Setting a Cement Plug/Squeezing Cement

A thermal cement squeeze must be conducted into the open-hole interval. The plug must extend from at or below the formation top to a minimum of 15 vertical metres above the formation top. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. If the licensee elects to apply a squeeze pressure to the cement, the ERCB recommends following the criteria set out in Option 2 of Section 5.4.7.1 (minimum cement volumes, final squeeze pressures, etc.).

5.4.8 Completed Horizontal Wells Across Multiple Formations

For a horizontal open-hole interval that penetrates multiple formations, each porous formation must have a thermal cement plug set in the open-hole section to either cover or isolate it from different porous formations. A minimum 30 vertical metre thermal cement plug is required, extending either a minimum of 15 vertical metres below the formation or the plug-back total depth, whichever is shallower, to a minimum of 15 vertical metres above the porous formation. The location of the plug must be confirmed by one of the approved methods described in Section 6.

If **any** of the horizontal intervals is a level-A interval, the uppermost interval must be abandoned in accordance with Section 5.4.7.1.

5.5 Groundwater Protection

All nonsaline groundwater must be covered by cement. Groundwater protection must include the identification and isolation of the BGWP from hydrocarbon formations below, as well as the identification and isolation of all protected intervals that are above the BGWP.

To determine the BGWP depth for a well, the licensee must refer to the BGWP query tool available on the ERCB Web site www.ercb.ca under the DDS system (ERCB : Reports : Base of Groundwater Protection). The elevations provided are subsea and must be converted to kelly bushing (KB).

A protected interval is an interval that is above the BGWP and is defined as:

- any lithology with greater than 3 per cent porosity, or
- any coal seam.

Protected intervals may be grouped together (i.e., not isolated), provided that

- the lithologies with greater than 3 per cent porosity are not separated from each other by more than 10 m, and
- the coal seams are not separated by
  - more than 30 m of non-coal-bearing-strata, or
  - a sandstone (of any vertical extent) with greater than 3 per cent porosity.

5.5.1 Remedial Cementing of Protected Intervals

The licensee must use one of the following options to cover or isolate all protected intervals.

Option 1—Removing Casing and Setting a Cement Plug

Prior to pulling the casing, all downhole abandonment operations must be completed in accordance with *Directive 020* (or any nonroutine approval that may be in place).

If the casing is free below the BGWP, the licensee may cut and pull the casing. Casing removal schemes that meet the following requirements are **routine**. Any casing string other than the surface casing may be removed.

The cut point must be identified at or below the BGWP.

A permanent bridge plug must be set a minimum of 15 m below the intended cut point.

The bridge plug must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

The casing must be cut at the cut point identified.

Once the casing is cut and pulled, a cement plug must be set from the bridge plug to a minimum of 15 m above the surface casing shoe.

The cement plug must be located and pressure tested at a stabilized pressure of 7000 kPa for 10 minutes.

If the casing is unsuccessfully recovered, the Well Operations Section must be contacted.

Option 2—Perforating, Milling, or Slotting Casing

The licensee must perforate, mill, or slot the casing at the BGWP and attempt to establish circulation to the surface with nonsaline water. A maximum of 1 m^3 of acid may be used to establish circulation.

5.5.1.1 Circulation to Surface Is Successful

If circulation to surface is successful, the licensee must pump cement to surface by either setting a cement retainer above the perforations or the milled or slotted casing or by circulating cement to surface and leaving a cement plug across the perforations, milled, or slotted casing.

- If a retainer is used, the cement retainer must be set within 15 m above the perforations or the milled or slotted casing. The retainer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. Following pumping of cement, the retainer must be capped with a minimum of 8 vertical metres of class "G" cement.
- If a retainer is not used, a bridge or wiper plug must be set as close as possible below the perforations or the milled or slotted casing. The cement top inside the casing must be a minimum of 15 vertical metres above the perforations or the milled or slotted casing. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested to a stabilized pressure of 7000 kPa for 10 minutes.

5.5.1.2 Circulation to Surface Is Unsuccessful

If circulation to surface is unsuccessful, the licensee must attempt to establish a feed rate. If a feed rate can be established, cement must be squeezed (without exceeding the formation fracture pressure) into the perforations or the milled or slotted casing.

- If a retainer is used for the above operations, the cement retainer must be set within 15 m above the perforations or the milled or slotted casing. The retainer must be pressure tested at a stabilized pressure of 7000 kPa for 10 minutes. The retainer must be capped with a minimum of 8 vertical metres of class "G" cement.
- If a retainer is not used for the above operations, a cement plug must be set from a minimum of 15 vertical metres below the perforations or the milled or slotted casing to a minimum of 15 vertical metres above the perforations or the milled or slotted casing. The location of the plug must be confirmed by one of the approved methods described in Section 6. The plug must be pressure tested to a stabilized pressure of 7000 kPa for 10 minutes.

If a feed rate is unsuccessful, the perforations must be abandoned in accordance with one of the options set out in Section 5.3.5.2.

The licensee must then evaluate the wellbore to ensure that all protected intervals above the BGWP are isolated from each other.

5.5.2 Requesting a Groundwater Protection Waiver

The ERCB requires that all protected intervals be covered by cement. In specific situations, the ERCB may consider industry requests to waive the requirement to cover protected intervals. Abandonment operations for which a groundwater waiver is requested are nonroutine.

A written assessment containing the required information must be completed by the licensee and submitted to the Well Operations Section (see Section 2.1).

The written assessment must include

- the surface casing/conductor pipe depth,
- the production casing cement top(s) and method of identification,
- the BGWP, and
- confirmation by a qualified log analyst of the absence of protected intervals between the cement top and the surface casing/conductor pipe setting depth.

A request for a groundwater protection waiver must be approved by the ERCB prior to beginning any work.

6 Confirming Location of Cement Plugs

6.1 Methods for Confirming Plug Locations

There are four ERCB-approved methods for confirming the location of plugs. Method 1 is the preferred method. If Methods 2, 3, or 4 are used, care must be taken to ensure that the cement plug is not "strung out."

Method 1—Confirmation of Plug Location with Drill Pipe

This method uses a strap tally—measuring and counting joints of drill pipe—and subsequent tally adjustments to determine the drill pipe setting depth for each plug and the location of the plug top.

The location of the plug top must not be confirmed until after 8 hours from the time the plug was run or after surface samples have set. The minimum force with which plugs must be located is 1800 decanewtons or string weight, whichever is less.

Note that the use of slick line or wireline is *not* an approved plug top locating method.

The licensee must include the following details in the tour report:

- cement type, mass (tonnes), and slurry volume (in cubic metres) for each plug,
- drill pipe, tubing, or coil tubing setting depth (strap tally and tally adjustments must be shown on the tour reports to support the reported pipe/tubing setting depth),
- force (in decanewtons) with which the plug top was felt,
- plug top depth (strap tally and tally adjustments must be included to support the reported plug top location), and
- date and time that the location of each plug was confirmed.

Method 2—Direct Density Plug Logging

This method uses a radioactive source and a detector run on wireline.

Tool calibration must be performed at least once per job. The resulting log must show fluid density, fluid gradient, or cement percentage.

The difference between the cement density and the density of the drilling fluid must be at least 300 kilograms per cubic metre (kg/m^3) (or 2.9 kPa/m).

A minimum of 25 m of plug must be logged to accurately determine the plug top. The position of the plug top is interpreted as a suitable intermediate point between drilling fluid and cement slurry density, commonly 1600 kg/m^3 (or 15.7 kPa/m).

A plug log must be produced for this method and must be submitted to the ERCB Resource Information Team, Well Log Group. A calibration time and results must be included on the log.

Method 3—Hydrostatic Pressure Plug Logging

This method uses a pressure transducer run on wireline. As the tool travels, the difference between pressure readings produces a fluid gradient, which may then be converted to fluid density.

The tool must be run continuously and must be calibrated in accordance with Section 11.110 of the *Oil and Gas Conservation Regulations*. The resulting log must show fluid density, fluid gradient, or cement percentage.

The difference between the cement density and the density of the drilling fluid must be at least 300 kg/m^3 (or 2.9 kPa/m).

A minimum of 25 m of plug must be logged to accurately determine the plug top. The position of the plug top is interpreted as a suitable intermediate point between drilling fluid and cement slurry density, commonly 1600 kg/m^3 (or 15.7 kPa/m).

A plug log must be produced for this method and must be submitted to the ERCB Resource Information Section. The serial number, range, and date of last calibration of the gauges must be shown on the plug log.

Method 4—Radioactive Tracer Logging

This method uses a radioactive tracer introduced into the lead slurry. The location of the plug top is confirmed by detection of the tracer with a gamma ray logging tool. Since the radioactive logging method is locating the radioactive tracer, adequate precautions should be taken to properly mix the tracer with the cement to prevent channelling of the cement during pumping and displacement. The ERCB recommends that spacer fluid be used before the cement to prevent channelling.

The resulting log must show the location of the tracer, which is then interpreted as the plug top.

A plug log must be produced for this method and must be submitted to the ERCB Resource Information Section.

6.2 Plug Log Submission Requirements

Plug logs generated for methods 2, 3, and 4 must be submitted within 30 days of completing downhole abandonment operations.

The licensee must ensure that all of the following reporting requirements for open-hole abandonments are met. Although some of the information required is obtained from third parties on the well site (e.g., the slurry volume), the licensee must ensure that the information is accurate.

The requirements for plug logs are as follows:

A gamma ray or other type of suitable log that can be correlated to the open-hole log suite must be run for depth-control purposes. The base gamma ray log must be traced onto the plug log and depth corrections made as necessary, or the licensee must include remarks on the plug log for all gamma ray deflections that were visually correlated, as well as any depth corrections made.

A collar locator must be run in conjunction with tally adjustments to determine the drill pipe setting depth for each plug. In the absence of a collar locator, strap tally and tally adjustments must be used.

The drill pipe must be pulled above the top of the plug prior to confirming its location with a logging tool.

If the plug logging method fails to clearly indicate the plug top, the licensee must confirm the location of the plug top with drill pipe according to method 1.

The licensee must submit the following information with the plug log:

- mud density and bit size,
- interval to be cemented,
- drill pipe setting depth (strap tally and adjustments used in conjunction with the collar locator must be included to support the drill pipe setting depth),

- mass in tonnes and volume in cubic metres of cement that was run during placement of the plug (this includes the calculated volume plus any excess run),
- type/class of cement used, including any additives and the average slurry density,
- volume of displacement fluid used,
- plug placement time and logging time,
- interval logged,
- depth at which the cement top was logged,
- quality of cement samples (this is a visual analysis usually conducted by the cementing company; the analysis consists of time required for samples to set at surface), and
- a trace of the base correlation log shown on the plug log or remarks for all gamma ray deflections that were visually correlated and any depth corrections made.

7 Testing and Inspection Requirements

Before beginning any surface abandonment operation, the licensee must perform certain required tests on the well, as detailed below.

It is advisable to perform the gas migration and surface casing vent flow tests prior to beginning downhole abandonment operations to avoid having to reenter the well to correct a wellbore problem. If testing indicates the presence of gas migration (GM), a surface casing vent flow (SCVF) or a leaking plug(s), the source of the leak must be identified and repaired prior to surface abandonment.

7.1 Gas Migration Testing for Open- and Cased-Hole Wells

7.1.1 Gas Migration Test Area

GM testing must be conducted on cased-hole well abandonments where the well does not have a surface casing vent assembly and on all wells that are located in the required test area (see Figure 6).

The required test areas are

- Townships 45-52, Ranges 1-9, W4M, and
- Townships 53-62, Ranges 4-17, W4M.

To reduce the chance of reentering a well for repair, the ERCB recommends that all wells be tested for GM prior to abandonment. See Appendix 2 for a suggested method of GM testing.

7.1.2 Notification of Gas Migration

If a GM problem is detected, the licensee must notify the ERCB through the DDS system (ERCB : Incident : Surface Casing Vent Flow/Gas Migration) within 30 days of detection. See *ID 2003-01* for definitions of serious and non-serious GM.

If GM is discovered *after* surface abandonment has been completed on a well, the licensee must notify the ERCB through the DDS system (ERCB : Incident : Surface Casing Vent Flow/Gas Migration) within 30 days of detection.

The licensee is required to repair the GM and must obtain a nonroutine abandonment approval prior to reentering and reabandoning the well.

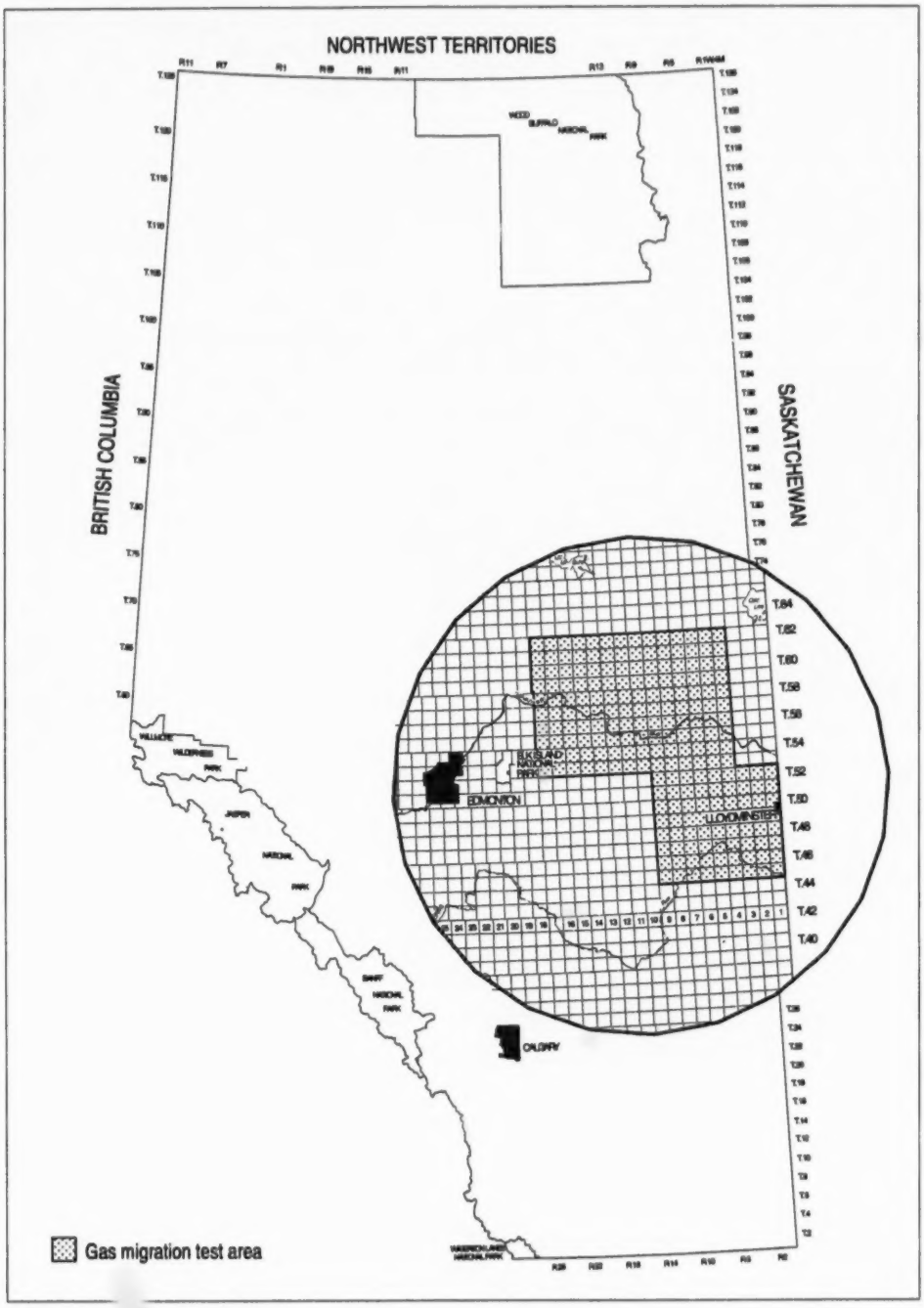

Figure 6. Gas migration test area

7.2 Fluid Level Test for Open-Hole Wells

Prior to conducting a surface abandonment, the licensee must conduct a **fluid level test** to determine if there are any leaking plugs. The fluid level test must be performed a minimum of 5 days after downhole abandonment operations have been completed. To perform the test, the licensee must visually inspect the well to ensure that the fluid level inside the casing is static and there are no gas bubbles present. In the event of a leaking plug, the licensee must prepare

a reabandonment program and submit a nonroutine abandonment request via the DDS system (Licence Abandonment : Non-routine Well Abandonment) within 30 days of discovery of the leaking plug.

Fluid level testing is not required for oil sands evaluation and test hole wells where the fluid required to fill the hole coincided with the calculated pipe displacement volume (see Section 4.6).

If a well is in the designated site inspection region (Figure 7), the licensee must wait until the well passes an ERCB site inspection before cutting and capping the well. To schedule a site inspection, the licensee must contact the ERCB Medicine Hat Field Centre at 403-527-3385 within 24 hours after conducting downhole abandonment operations. The licensee must provide the well location, company contact name and phone number. The Medicine Hat Field Centre will arrange a site inspection of the well.

The site inspection region includes

- Townships 7–14, Ranges 12–17, W4M, and
- Townships 15–18, Ranges 10–13, W4M.

Until the well has been inspected, the surface casing must be left open, with fluid visible and protected from freezing. The well will be visually inspected by ERCB staff for leaking plugs and the results communicated to the licensee.

7.3 Surface Casing Vent Flow Test for Cased-Hole Wells

Prior to conducting a surface abandonment, the licensee must conduct a **surface casing vent flow test** to determine if gas, liquid, or any combination of substances is escaping from the casing vent assembly.

A bubble test must be conducted with a hose 2.5 cm below the water surface for a minimum of 10 minutes. If any bubbles are present during the 10-minute test, the well has a vent flow.

7.3.1.1 Rate Determination

If bubbles were present during the bubble test, a SCVF rate test must be conducted. This test should be continued until a stabilized rate is obtained.

The licensee must use either a positive displacement gas metre or an orifice well tester to measure vented gas volumes.

7.3.2 Determination of Stabilized Shut-in Surface Casing Pressure

If bubbles were present during the bubble test, the SCV must be shut in until a stabilized pressure is obtained. The pressure is considered stabilized if the change in pressure is less than 2 kPa/hr over a six-hour period.

7.3.3 Determination of Serious or Non-Serious Vent Flow

The licensee must determine if the vent flow is serious or non-serious in accordance with the criteria set out in *ID 2003-01*.

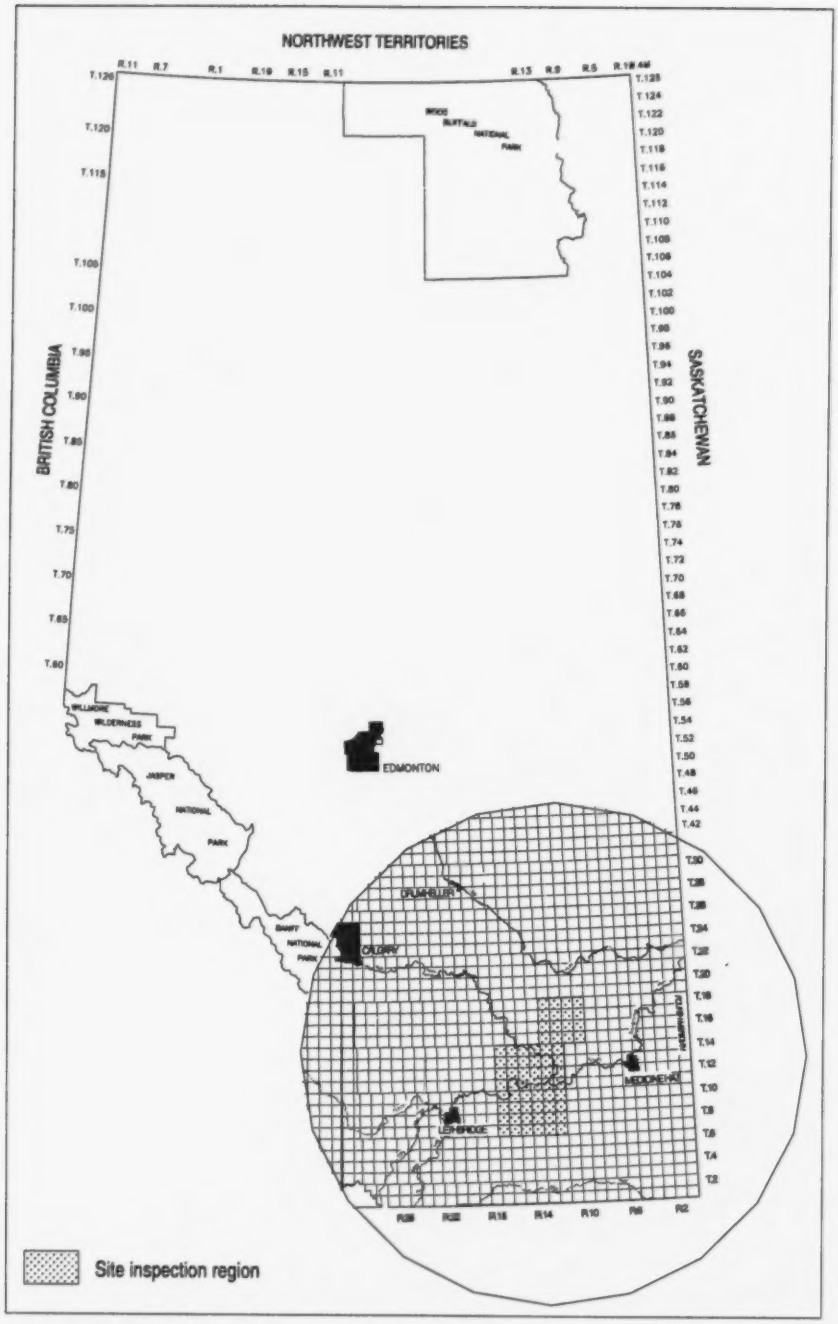

Figure 7. Site inspection region

7.3.4 Notification of SCVF

If any bubbles were present during the 10-minute SCVF test, the licensee must notify the ERCB via the DDS Surface Casing Vent Flow/Gas Migration (SCVF/GM) service within 30 days of detection and repaired in accordance with *ID 2003-01*.

8 Surface Abandonment

Surface abandonment is the cutting off of casing string(s) and the capping of a well.

The licensee must not begin surface abandonment until the required testing (see Section 7) has been performed and the test results indicate the absence of any wellbore problem.

Surface abandonment must be completed within 12 months after downhole abandonment operations.

If the well is being abandoned due to an order of the ERCB, the licensee must begin surface abandonment as directed.

The licensee must inform all affected parties, including the landowner and/or occupant, of a planned surface abandonment before beginning any work.

Surface abandonment must be reported through the DDS system (ERCB : Licence Abandonment : Well Licence Abandonment) within 30 days of completing the operation.

Surface equipment, cement pads, debris, and produced liquids associated with the well licence must be removed within 12 months of the cutting and capping operation.

The licensee must retain the record of the removal and cleanup activities and make this available to the ERCB upon request.

8.1 Cutting and Capping

The casing string(s) must be cut off a minimum of 1 m below the final contour elevation, with the following exceptions:

- If the well is in an area with special farming practices, such as deep tillage, drainage works, or peat lands, or is within 15 km of an urban development, the casing string(s) must be cut off a minimum of 2 m below final contour elevation.

If the well is located in an area where surface mining will be conducted,

- a cement plug must be circulated from the uppermost abandonment plug to 15 m below the intended strip mining depth, and
- above the strip mining depth, the casing must be cut at intervals agreed upon by the mining operator.

Surface, intermediate, and production casing strings must be capped at surface with a steel plate that is fastened and installed in a manner as to prevent any potential for pressure to build up within the casings while restricting access to the casing strings at surface.

Note that the "wedding cake" style cut and cap is now permitted.

The licensee must retain the record of the capping and venting procedure used in the well file for the life of the well. The documentation must be made available to the ERCB upon request.

Typical cased-hole abandonment schematics are shown in Figures 8 and 9.

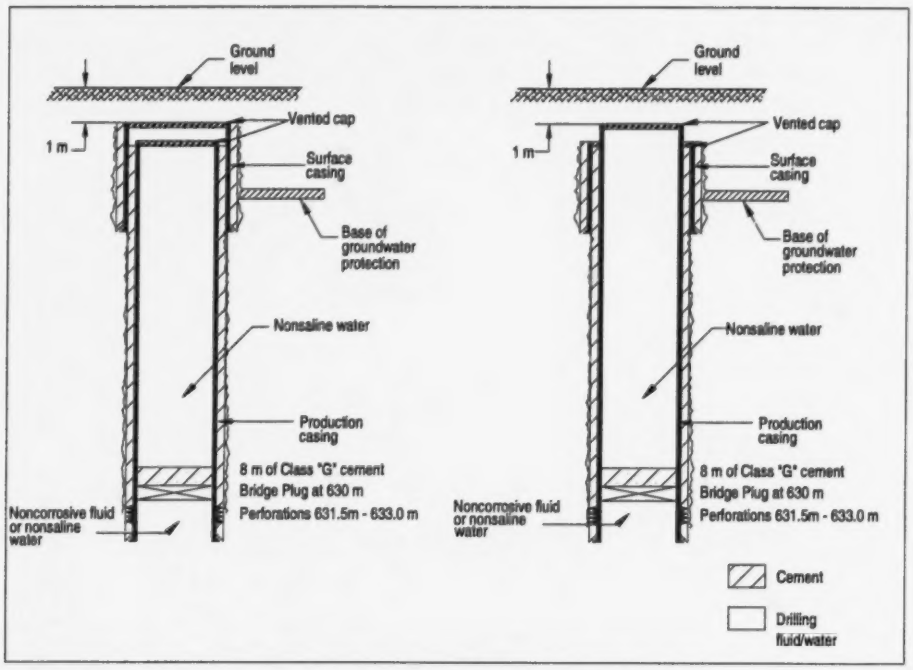

Figure 8. Examples of cased-hole abandonment for non-level-A intervals

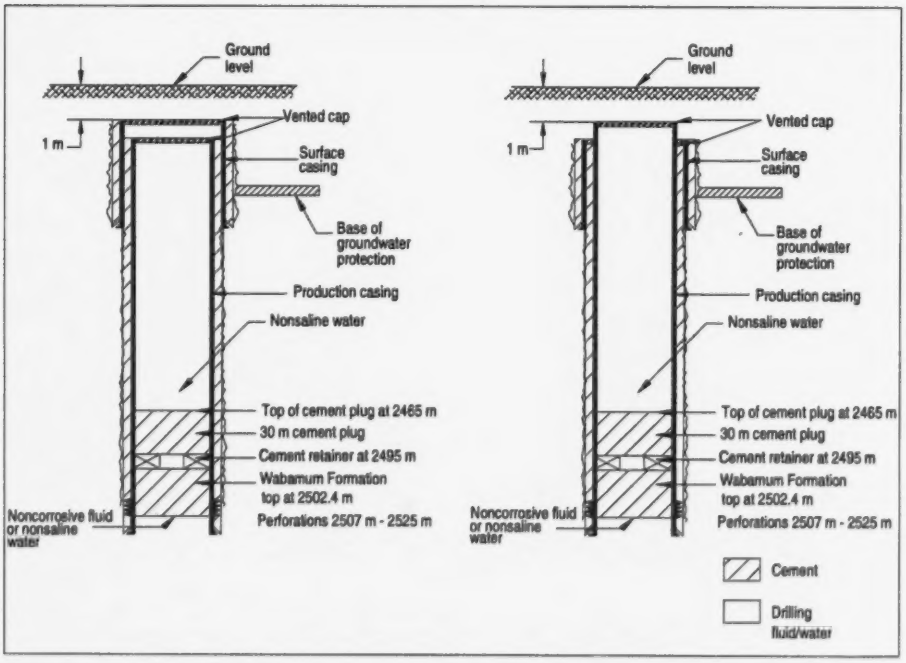

Figure 9. Examples of cased-hole abandonment for level-A intervals

9 Compliance Assurance

9.1 Compliance Assurance and Enforcement Process

The ERCB's enforcement process is specified in *Directive 019*: ERCB Compliance Assurance—Enforcement. A list of risk-assessed noncompliances is available on the ERCB Web site www.ercb.ca under ERCB Home : Industry Zone : Compliance and Enforcement : Risk Assessed Noncompliance.

The licensee must keep all test results and abandonment details for abandoned wells.

If a licence for an abandoned well is transferred, the new licensee assumes all responsibility for the control or further abandonment of the well and the responsibility for the costs of doing that work.

The ERCB will conduct compliance assessments for all requirements listed in this directive to confirm the licensee's compliance and to help measure the effectiveness of the abandonment process.

The licensee must provide any supporting information related to these compliance assessments within 20 working days of a request by the ERCB.

Based on the results of the assessment, ERCB may order a licensee to reenter and reabandon a well if conditions warrant.

Appendix 1 Definitions for the Purposes of *Directive 020*

Cased-hole well abandonment	The downhole abandonment of a completed or cased well.
In situ coal gasification/liquification	The intentional thermal or chemical conversion of coal into synthetic coal gas or liquid in an underground seam.
Level-A interval	For the purpose of this directive, level-A intervals are intervals that • have been used for disposal of 1a or 1b fluids, • have been used for injection of acid gas, • have an H_2S concentration in excess of 15 per cent, or • have been designated as critical sour. This evaluation is done on a well (not a pool) basis.
Mannville Group equivalent	The comparable geological formation to the Mannville, such as the Luscar or Blairmore Groups or Spirit River Formation.
Noncompleted well	A well that has not been perforated and has no open-hole section.
Nonsaline water	Water that has total dissolved solids less than or equal to 4000 milligrams per litre.
Open-hole well abandonment	The downhole abandonment of an open-hole well after drilling is complete but before the rig is released.
Plug back	The downhole abandonment of a portion of an open-hole well.
Porous zone	A zone that • has carbonates with effective porosity greater than 1 per cent, • has sandstones with effective porosity greater than 3 per cent, • has offset production, regardless of the porosity, or • has drillstem test formation fluid recoveries greater than 300 linear metres or gas volumes greater than 300 cubic metres.
Protected interval	• Any lithology with greater than 3 per cent porosity. • Any coal seam.
Remedial cementing	Cementing operations performed to repair primary-cementing problems or to treat conditions arising after the wellbore has been constructed.
Surface abandonment	The cutting off of casing string(s) and the capping of a well.
Thermal cement	A cement blend that after curing for 48 hours has a minimum compressive strength of 3500 kPa at a temperature of 360°C.
"Wedding cake" style cut and cap	A method of capping a well that has the production casing string extending beyond the intermediate and/or surface casing. If the well has intermediate casing, the intermediate casing would extend beyond the surface casing. All the casing strings are capped in a manner that will prevent the buildup of pressure inside any of the casing strings.
Zonal abandonment	The abandonment of a single pool completion within a cased hole or the downhole abandonment of an open-hole interval in a cased hole.

Appendix 2 Suggested Procedure for Gas Migration Testing

The Lloydminster Area Operations Group Gas Migration Team (LAOGMT) drafted the following testing procedures. While the ERCB endorses these procedures for use within the province, it also recognizes that there are other methods of testing for gas migration; thus, the following procedure is not the only method of determining the existence of gas migration. The specifics of the test method used by the licensee must be available for review upon request.

The licensee must follow the ground disturbance requirements described in the *Pipeline Act* and *Regulation*.

Testing is to be done only in frost-free months. Periods immediately after a rainfall have to be avoided.

If less than full-scale readings are obtained, the soil horizon should be examined to ensure that readings are not the result of contaminated soils due to spills of diesel fuel, solvents, oil, etc. If contaminated soils are suspected, retesting is recommended.

Instrumentation should be calibrated regularly and checked daily when in use.

Sample testing points have to be selected to ensure that potential gas migration is detected.

Recommended Test Point Locations

- two within 30 cm of wellbore on opposite sides
- at 2 m intervals outward from the wellbore every 90° (a cross with the wellbore at centre) to a distance of 6 m
- at any points within 75 m of wellbore where there is apparent vegetation stress

Recommended Equipment

- equipment capable of penetrating a minimum of 50 cm deep and a maximum of 64 millimetres (mm) in diameter
- calibrated explosion meter or other instrument capable of detecting hydrocarbon at 1 per cent lower explosive limit (LEL)
- equipment or material to seal hole at surface while soil gases are being evacuated from the soil through the instrument

Testing Procedures

- Perform instrument check (calibration, voltage, zero, etc.).
- Make a hole a minimum of 50 cm deep.
- Isolate the hole from atmospheric contaminations.
- Insert hose, wand, or other equipment a minimum of 30 cm into hole, maintaining a seal at surface to prevent atmospheric gas and soil gas mixing.
- Withdraw soil gas sample. The volume, rate, etc., will depend on the instrumentation being used. Ensure that a sufficient sample is removed to purge lines and instrumentation.
- Record observations.
- Purge instrument and lines.

Appendix 3 Suggested Procedure for Surface Casing Vent Flow Testing

While the ERCB endorses these procedures for use within the province, it also recognizes that there are other methods of testing for a SCVF; thus the following procedure is not the only method of determining the existence of a SCVF. The specifics of the test method used by the licensee must be available for review upon request.

Bubble Test

Recommended Equipment

- a container of water (from 500 millilitres to 1 litre)
- pipe fittings, small hose (minimum 6 mm, maximum 12 mm inside diameter), or other equipment necessary to direct gas flow from vent downward into the water container

Testing Procedures

- Ensure that there are no gas leaks at fittings and welds.
- Ensure that all valves in the vent line are open.
- Connect test fittings to vent so that gas flow can be directed into the container of water.
- Immerse hose a maximum of 2.5 cm (1 inch) below the water surface.
- Observe for 10 minutes. Note any gas flow (i.e., bubbles) indicating a positive vent flow.
- Record observations.
- If there is a positive vent flow, determine the rate and stabilized shut-in surface casing pressure.

Rate Determination

Equipment selection should be based on previous observations indicating what flow rate and pressure range can be expected. A positive displacement meter is necessary to measure low volumes accurately. An orifice well tester (with proper orifice plate) may provide satisfactory measurements if 24-hour shut-in pressure is 200 kPa or greater and builds quickly.

The licensee must install and use the equipment according to manufacturer's instructions, keeping in mind that

- the pressure/volume range of the equipment must not be exceeded,
- the fittings, wellhead, etc., must not be leaking, and
- unless specifically directed by the ERCB to close them, casing vents must be left open when equipment is removed.

Determination of Stabilized Shut-in Surface Casing Pressure

Recommended Equipment

- pressure gauge or single pen static pressure recorder
- pressure relief valve calibrated to release at a pressure equal to 11 kPa/m x length of surface casing setting depth (m)

Testing Procedures

- Install pressure recorder or pressure gauge and pressure relief valve.

- Ensure that there are no gas leaks at fittings and welds.
- If a chart is used:
  - If pressure has not stabilized, it will be necessary to change the recorder to cover a longer time period in order to achieve a maximum shut-in pressure. Repeat the first two steps.
  - If chart pressure reaches the maximum pressure relief valve setting, record result.
  - If chart pressure stabilizes and is below pressure relief valve setting, record result.
- If a pressure gauge is used, monitor the readings to determine when a stabilized maximum pressure is obtained and record this value.
  - If gauge pressure reaches the maximum pressure relief valve setting, record result.
- Remove equipment and leave casing venting.